EXPLOITING THE BOW-TIE EFFECT FOR CHARACTERIZING MODIS PERFORMANCE

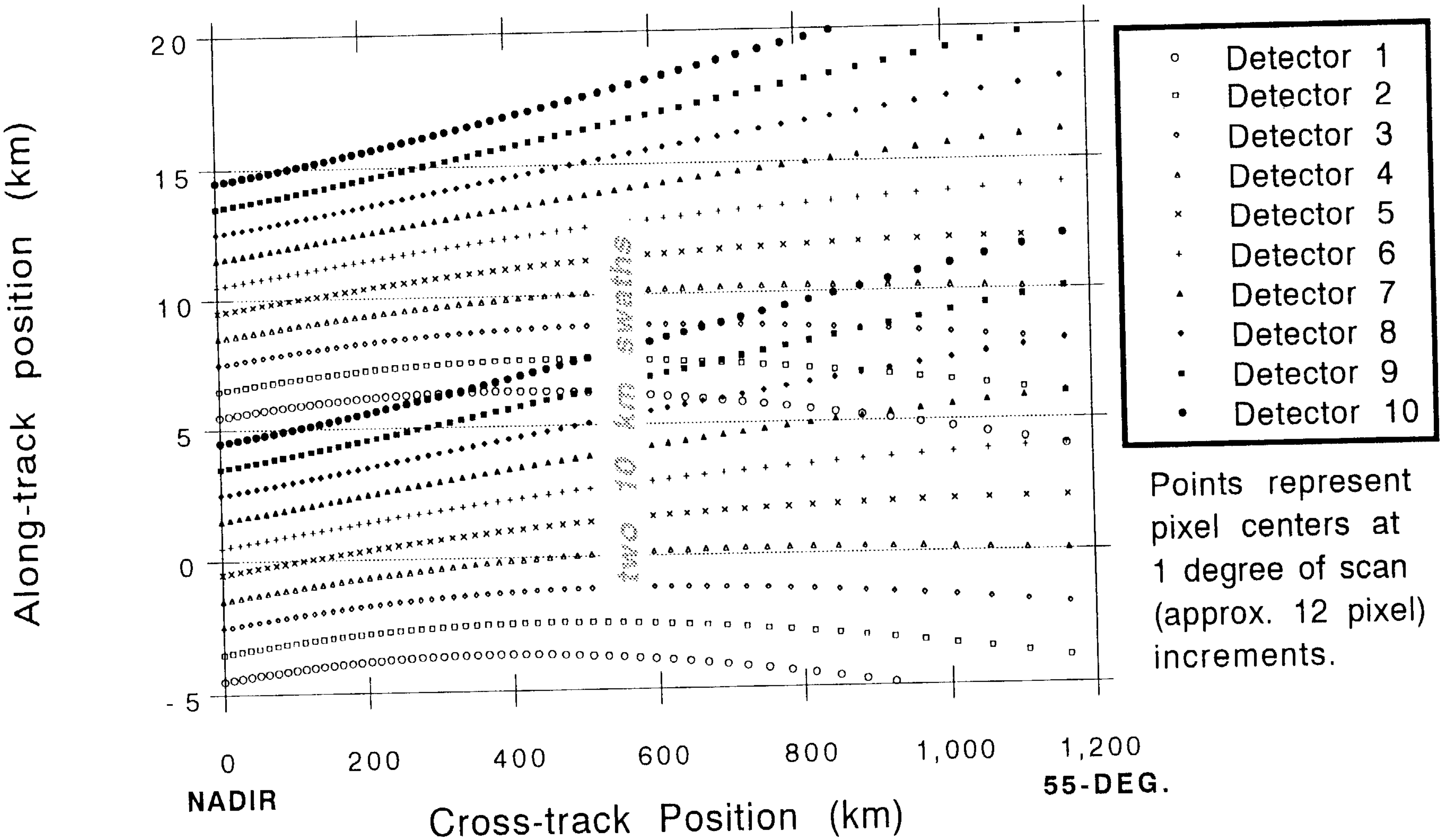
Stephen G. Ungar

MODIS Science Team Meeting
May 4, 1994

Attachment 6

MODIS Scan Pattern

(10 element array, 1 km GFOV)



Points represent pixel centers at 1 degree of scan (approx. 12 pixel) increments.

Factors Affecting Intercomparison of Bow-tie Effect Induced Overlapping Detector Observations

- The relative performance (i.e. radiometric response) of the detectors being compared.

- Uncertainties in the collocation of the footprints associate with each of these detectors.

- Differences in the optical properties between the two surfaces of the scan mirror.

What Can be Learned from Bow-tie Effect Induced Overlapping Detector Observations

- The relative performance (i.e. radiometric response) of the detectors being compared.
  By analysis over large scale homogeneous areas.

- Uncertainties in the collocation of the footprints associated with each of these detectors.
  By sensitivity analysis over inhomogeneous areas.

- Differences in the optical properties between the two surfaces of the scan mirror.
  By partitioning observations according to mirror surface.

Exploiting Bow-tie Effect Induced Overlapping Detector Observations

- Derive and monitor the within-band detector-to-detector relative calibration for *all* detector pairs.

- Evaluate and monitor system misalignments and aspects of the geolocation procedure.

- Determine and monitor the relative reflectance between the two scan mirror surfaces as a function of angle and wavelength.

ILLUSTRATIVE APPROACH TO EXPLOITING BOW-TIE EFFECT INDUCED OVERLAPPING DETECTOR OBSERVATIONS

The detailed formulae which follow this page do not necessarily represent the scheme which will be adopted by MCST for extracting information from overlapping observations due to the MODIS scan geometry (i.e. the Bow-tie Effect). The exact approach will be worked through feedback from the Peer Review process as well as interaction with the MODIS Science Team. The formulae do, however, serve as an example of a concrete proposal for extracting the information alluded to in the preceding viewgraphs.

Stephen G. Ungar

May 4, 1994

Let us assume that, based on the geolocation calculations, we predict a coincidence between detector A on the current scan and detector B on the preceding scan.

define:

$A_x^s \equiv$ sample $\underline{x}$ for detector $\underline{A}$ on scan $\underline{s}$;

and

$\mathcal{A}(A_x^s) \equiv$ projected surface area for A_x^s

then $\exists$ an $\underline{n}$ and $\underline{m}$

such that

$$\mathcal{A}(A_n^s) \cap \mathcal{A}(B_m^{s-1}) \approx \mathcal{A}(A_n^s) \cup \mathcal{A}(B_m^{s-1})$$

more rigorously, we may set an overlap threshold $\mathcal{T}$ (e.g. $\mathcal{T}$ = 0.9 for 90% overlap) and require:

$$\frac{\mathcal{A}(A_n^s) \cap \mathcal{A}(B_m^{s-1})}{\mathcal{A}(A_n^s) \cup \mathcal{A}(B_m^{s-1})} \geq \mathcal{T}$$

Now we may extract observation pairs A_n^s, B_m^{s-1} for all scans (i.e. all values of s) along an orbital segment. To simplify notation,

define:

A_n, B_m $\equiv$ the set of paired (coincident) observations

where:

n, m $\Rightarrow$ n(s) and m(s-1) for all values of s.

define:

$\mathcal{V}(A_n, B_m) \equiv$ the variance of A_n, B_m

and the theoretical inter-detector calibration, $\mathcal{F}$, relating the response of detector B to that of detector A through:

$$B = \mathcal{F}(A)$$

$$\therefore \quad \mathcal{V}(A_n, B_m) = \frac{1}{S}\sum_{s=1}^{S}\left(B_m^{s-1} - \mathcal{F}(A_n^s)\right)^2.$$

To check for misalignment, we may construct the following series of, for example 9, scattergrams based on the predicted pair A_n, B_m :

find:

A_{n+i}, B_{m+j} for $-1 \leq i, j \leq +1$

calculate:

$V(A_{n+i}, B_{m+j})$ for $-1 \leq i, j \leq +1$

then:

$$\frac{\partial^2 V}{\partial i \partial j} \approx 0 \quad \text{for } i, j = 0 \quad \Rightarrow \quad \text{Alignment}$$

if this is not the case, define distribution function over <u>many</u> orbit segments as follows:

$FD(A_{n+i}, B_{m+j}) \equiv$ frequency of minimum V occurring at A_{n+i}, B_{m+j}

adjust geocorrection to maximize $FD(A_n, B_m)$

Assume the response of detector B is linearly related to that of detector A as follows:

$$B = \alpha A + \beta$$

To account for differences between the two scan mirror surfaces assume:

$$A'_1 = S_1 A \qquad B'_1 = S_1 B$$
$$A'_2 = S_2 A \qquad B'_2 = S_2 B$$

where:

A, B are the detector responses for a perfectly reflecting scan mirror surface;

S_n is the effective reflectance of mirror surface <u>n</u>;

A'_n, B'_n are the detector responses for reflectance factor S_n

We may define the relative reflectance of surface 2 to that of surface 1 as:

$$\kappa \equiv \frac{S_2}{S_1}$$

Now we may partition the coincident detector pair observations discussed earlier into two sets:

detector A observations are from mirror surface 1
$\Rightarrow$ matching detector B observations from surface 2

detector A observations are from mirror surface 2
$\Rightarrow$ matching detector B observations from surface 1

This results in two sets of scattergrams which may be fitted as follows:

$$B'_2 = \alpha'_1 A'_1 + \beta'_1 \qquad\qquad B'_1 = \alpha'_2 A'_2 + \beta'_2$$

Now for some rudimentary algebraic substitution:

$$S_2 B = \alpha'_1 S_1 A + \beta'_1 \qquad\qquad S_1 B = \alpha'_2 S_2 A + \beta'_2$$

$$B = \alpha'_1 \frac{S_1}{S_2} A + \frac{\beta'_1}{S_2} = \alpha'_2 \frac{S_2}{S_1} A + \frac{\beta'_2}{S_1}$$

$$\alpha = \alpha'_1 \frac{S_1}{S_2} = \alpha'_2 \frac{S_2}{S_1} \qquad\qquad \beta = \frac{\beta'_1}{S_2} = \frac{\beta'_2}{S_1}$$

$$\therefore \quad \alpha = \sqrt{\alpha'_1 \cdot \alpha'_2} \qquad\qquad \kappa = \sqrt{\frac{\alpha'_2}{\alpha'_1}} = \frac{\beta'_1}{\beta'_2}$$

Using selected detector pairs we may find the wavelength and scan angle dependance:

$\kappa \rightarrow \kappa(\lambda,\theta)$

We may use the ability to determine κ from the β' estimates, independant of the α' estimates, in conjunction with the statistical spread in the ensemble of coincident detector pair observations to estimate the uncertainty in κ:

$$\varepsilon \equiv \frac{\Delta\kappa}{\kappa}$$

We can determine a lower limit for β from:

$\beta \geq$ the maximum of β'_1, β'_2